in at least a portion of the spectral region visible to the human eye. In one embodiment the inventor's phosphor is an orange-red emitting phosphor comprised of AlN doped with manganese ions. In one embodiment the inventor's phosphor is produced by heating AlN powder in pressurized nitrogen gas with a Mn source.

Referring now to the drawings and in particular to FIG. **1**, one embodiment of the inventor's synthesis of the AlN:Mn phosphor is illustrated by a flow chart. The flow chart is designated generally by the reference numeral **100**. The flow chart **100** of FIG. **1** includes the steps describe below.

Step 1 designated by the reference numeral **102**: AlN powder—mixed with MnO

Step 2 designated by the reference numeral **104**: heat to 1700° C. in flowing nitrogen

Step 3 designated by the reference numeral **105**: heat to 2000° C. in 10 atm nitrogen

Step 4 designated by the reference numeral **106**: AlN:Mn phosphor produced.

The inventors synthesized the embodiment **100** of a phosphor not incorporating "critical rare earths" producing an orange-red emitting phosphor comprised of AlN doped with manganese ions. The inventors made the phosphor **100** by heating AlN powder, under flowing nitrogen gas, with MnO, with $Mn(NO_3)_2$, with $MnCO_3$, and with Al:Mn alloy. High emission quantum yields were obtained in all cases. There are other ways in which the inventor's phosphor can be synthesized.

Referring now to FIG. **2**, a graph illustrates the excitation and emission spectra of the inventor's phosphor. The inventors found that the AlN:Mn phosphor can be efficiently excited at 254 nm and the emission peak occurs near 600 nm. The calculated CIE coordinates of the AlN:Mn phosphor are X=0.60 and Y=0.37. The use of AlN:Mn will serve as alternative to the current use of europium-doped yttria (YEO), which has CIE coordinates of X=0.65 and Y=0.35.

The excitation and emission spectra for Y_2O_3:Eu (YEO) and AlN:Mn are shown in FIG. **2**. The excitation spectrum reveals a similar absorption strength at the mercury line of 254 nm, as well as a comparable intensity of emission in the orange-red 570-650 nm range. The similarity of the properties will allow the inventor's AlN:Mn phosphor to be used as a "drop-in" replacement for YEO. The inventor's phosphor provides a good match in the emission efficiency, and lumen maintenance to the current YEO phosphor and means that the AlN:Mn will be a direct replacement.

The integrated emission of the AlN:Mn phosphor in the 570-650 nm range is nearly identical to that of YEO, as shown in FIG. **3**. The absolute intensity of the AlN:Mn phosphor compared to YEO measured with a given 254 nm excitation source is 70%. Additionally, the AlN:Mn phosphor exhibits much less absorption through the visible, compared to YEO, as is desired for proper functioning of the tri-phosphor blend.

Fluorescent lighting is currently a multi-billion dollar industry worldwide, as these types of lamps are used ubiquitously in indoor venues today. A fluorescent lamp or fluorescent tube is a low pressure mercury-vapor gas-discharge lamp that uses fluorescence to produce visible light. An electric current in the gas excites mercury vapor which produces short-wave ultraviolet light (principal wavelength of 254 nm) that then causes a phosphor coating on the inside of the bulb to fluoresce, producing visible light. A fluorescent lamp converts electrical energy into useful light much more efficiently than incandescent lamps. The luminous efficacy of a fluorescent light bulb can exceed 90 lumens per watt, several times the efficacy of an incandescent bulb with comparable light output.

The inventors have developed a new high quantum efficiency phosphor based on Aluminum Nitride that has been found to offer properties amenable to use in fluorescent lighting. Aluminum nitride powder has been found to activate with manganese, producing bright orange-red light, when excited with the 254 nm UV line from a mercury discharge, offering a spectrum and conversion efficiency comparable to commercial orange-red phosphors, but without use of any rare-earth elements.

Referring now to FIG. **4**, one embodiment of the inventor's fluorescent lamp is illustrated. The embodiment of the inventor's fluorescent lamp is designated generally by the reference numeral **300**. The fluorescent lamp **300** includes the following components: a glass envelope **302**, Applicant's AlN:Mn phosphor coating **304** on the inside of the gas envelope **302**, mercury and an inert gas **308** contained within the glass envelope **302**, and electrodes **310**.

AlN in general is known to be reactive to water, though means to passivate the surface are known. The inventors have found several means by which this has been accomplished, including heating to above 800° C. and by treating AlN in phosphoric acid (see for example, Materials Research Bulletin, Vol. 32, 1173-I 179 (1997), and Journal of the European Ceramic Society Vol. 15, 1079-1085 (1995). In these articles, the authors show that the rate of reactivity with water can be greatly diminished by creating a passivating layer on the surface of the particles. Without limiting the potential means of passivating the surface of the particles in the AlN powder, the methods of heating the particles in air or oxygen and treating the particles in phosphoric acid are noted as reported methods of creating a thin surface layer to reduce the reactivity of AlN to environmental conditions on the basis of published literature. As AlN is currently used for such applications as heatsinks and insulators for electronics and for optical windows, researchers have previously been developing methods for passivating the surfaces to help enable ceramic processing of AlN into highly compacted materials.

The fluorescent lamp **300** uses fluorescence from the inventor's AlN:Mn phosphor **304** to produce visible light. The electrodes **310** are used to direct an electric current into the inert gas **308** within the glass envelope **302** to excite mercury vapor which produces short-wave ultraviolet light that then causes the inventor's AlN:Mn phosphor **304** on the inside of the glass envelope **302** to fluoresce and produce visible light.

The disclosed apparatus provides a fluorescent lamp including a glass envelope; at least two electrodes connected to the glass envelope; mercury vapor and an inert gas within the glass envelope; and a phosphor blend within the glass envelope, wherein the phosphor blend includes $Al_{(1-x)}M_xN$, where M may be comprised of one or more dopants drawn from beryllium, magnesium, calcium, strontium, barium, zinc, scandium, yttrium, lanthanum, cerium, praseodymium, europium, gadolinium, terbium, ytterbium, bismuth, manganese, silicon, germanium, tin, boron, or gallium and x has a value of $0<x<0.1$. In one embodiment the $Al_{(1-x)}M_xN$ is doped with at least M=manganese; wherein x has the value of $0<x<0.1$. In one embodiment the $Al_{(1-x)}M_xN$ contains between about 0.001% and 10% manganese. In one embodiment the $Al_{(1-x)}M_xN$ is in the form of a powder with grains in the 0.1-50 micron range. In one embodiment the powder is deposited onto the surface of the lamp envelope. In one embodiment the $Al_{(1-x)}M_xN$ phosphor is doped with carbon and/or oxygen, together with manganese by processing conditions or addition of dopants to induce an absorption at 254 nm and emission in at least a portion of the spectral region visible to the human eye. In one embodiment the fluorescent